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THE AURORA BOREALIS

L'Aurore Boréale. Étude générale des Phénomènes produits par les Courants électriques de l'Atmosphère. Par M. S. Lemström. (Paris: Gauthier-Villars, 1886.)

Resultate der Polarlicht-Beobachtungen angestellt im Winter 1882 *und* 1883 *auf den Stationen Kingua Fjord und Nain.* Von Dr. K. R. Koch. (Berlin: A. Asher and Co., 1886.)

THE organised and obstinate scientific curiosity of our time has not neglected the beautiful phenomenon of the "Polar Dawn." Yet its investigation is attended by peculiar difficulties and discouragements. It can be profitably conducted only amid scenes of frozen desolation, in the grisly depths of Arctic winter nights, under conditions taxing man's energy and resource to live, to say nothing of observing. The appearances in question are, moreover, as elusive as they are surprising. They promptly kindle the imagination, but leave the understanding, unless prepared by special study to apprehend something of their causes, baffled and helpless. Nevertheless, auroral research, though Nature seem to frown upon it, has been pursued with indefatigable energy during the last half century. It has formed the principal object of some, it has occupied a prominent place in the programmes of all recent Polar expeditions; besides being furthered, with less heroic zeal, by writers and thinkers unequal or averse to the company of thermometers normally below the zero of Fahrenheit. Nor have these labours been thrown away. Much of the mystery long attaching to the evanescent splendours of Arctic skies has been dissipated. There is no longer any doubt as to the *kind* of explanation appropriate to them. Their laws and relationships have been, to a great extent, elucidated; a satisfactory theory of their origin is at hand; some circumstances of their occurrence, long in debate, have been attested on unquestionable authority.

An excellent specimen of the patient laboriousness by which these results have been brought about is afforded in the work of Dr. Koch, cited as one of our authorities. He was in sole charge of the German station of Nain, on the coast of Labrador, during the International Polar term 1882–83, and now presents us with the record of his observations there, together with those made simultaneously at the still more northerly post of Kingua Fjord. Although situated in about the latitude of Dundee—56° 33′—Nain appears to be, in point of climate, one of the grimmest localities accounted habitable on the face of the globe. Frost-bites were a quite common incident of Dr. Koch's daily experience; and furious winds, rendering the use of his meteoroscope impossible, often left him dependent upon the natural features of the solemn but forbidding landscape, for determining the azimuths of auroral bands and arches. As regards these phenomena, indeed, the station is admirably located. It lies close to the southern edge of, if not actually within, the zone of maximum frequency; auroræ are consequently numerous and intense, and appear almost indifferently above the northern or southern horizon. Their varying forms are beautifully delineated in the drawings which lend a greatly increased value to Dr. Koch's publication. Multiple arches, up to the number of eight, were frequently seen; and the incessant movements affecting them, both as a whole and in their parts, the transverse flashing of the rays set side by side to compose some of them, the torrential rushing of light along the paths others seemed to prepare for it, as well as the restless wanderings of the entire luminous structure up and down the sky, gave continual variety and animation to these strange exhibitions, while accentuating their baffling recalcitrance to exact measurement. No estimates of height were attempted at either Nain or Kingua Fjord; but there was a total absence of auroral appearances below the clouds, or otherwise unmistakably very near the earth, such as have been noted by M. Lemström and other observers in high latitudes. Luminous mists were, however, common. At times they suffused the whole sky; and shapeless masses of them constantly succeeded, and (at Kingua Fjord) were often the substitutes for the organised and definite forms of a perfect aurora. A sudden and wide-spread development of cirrus clouds was another curious secondary feature of the Nain polar lights. These were, at both stations, completely mute; not a suspicion of audibility attended their movements.

A no less intrepid observer than Dr. Koch is the author of the work with which we have coupled his in the heading of this article. M. Lemström's auroral researches began in 1868, when he was attached to the Swedish Polar Expedition commanded by Baron Nordenskjöld. They were continued during a sojourn of six weeks in Finnish Lapland in 1871, and were brought to a highly successful issue at Sodankylä in 1882-84. Finland held an honourable place among the eleven nations lately combined for a simultaneous attack upon the secrets of the Arctic circle; and the Professor of Physics in the University of Helsingfors was, by an almost inevitable choice, appointed chief of the Finnish meteorological station established in compliance with the terms of international agreement. Our readers are not unacquainted with the original line of work struck out by him in that capacity. Its upshot was to secure demonstrative evidence as to the *proximate* cause of the aurora borealis.

The book under review derives, then, a particular interest from its authorship. It is the production of a man who has devoted thought and labour without stint to the subject of which it treats, and has pushed the associated problems visibly nearer to solution. He now sums up the present state of knowledge as regards them in a well-arranged, concisely written, and copiously illustrated volume, recapitulating the most significant and surely established facts, fitting them, with the critical judgment bought by long experience, into their proper places, and expounding the theory best adapted to interpret and harmonise them.

Remarkably, as time went on, Halley's conjecture of a magnetic origin for auroræ gathered round it confirmatory circumstances entirely unknown to its author. Celsius and Hiorter noticed, in 1741, spasmodic disturbances of the magnetic needle coincident with the darting movements of northern lights. Wilcke, Ussher, and Dalton, ascertained, towards the end of the century, the close geometrical relations between the terrestrial magnetic system and all the various parts composing a fully developed auroral display: the corona forming in the magnetic zenith, the streamers flitting parallel to the line of the dip, the arch erecting its summit in the magnetic meridian. When Faraday succeeded in obtaining luminous effects through magnetic action, and Rudolf Wolf demonstrated the subjection of auroræ to an identical periodicity with magnetic variations, the case might have appeared complete.

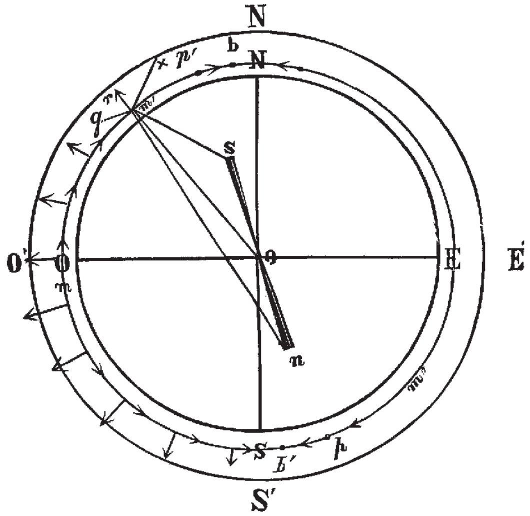
Yet the pure and simple magnetic theory of the aurora borealis, when attempted to be realised, either eluded the grasp of thought, or was found to involve admissions not very easy to make. Dalton, whose propensity towards forming distinct conceptions was a primary quality of his mind, had the courage to give it definite shape in 1793 (in his "Meteorological Observations and Essays"). Compelled, as he supposed, by the exigencies of observation, he conceived an envelope of an elastic fluid partaking of the nature of steel to replace atmospheric air at a height of about a hundred miles, and to supply the material alike of arches and streamers, shown, by their disposition in space, to be of a ferruginous character. It can scarcely be wondered at that the idea, in spite of Biot's adoption and development of it, failed to strike root. More vitality was in Canton's interrogative suggestion forty years earlier: "Is not the aurora borealis the flashing of electrical fire from positive towards negative clouds at a great distance, through the upper part of the atmosphere, where the resistance is least?" (Phil. Trans., vol. xlviii. p. 357.)

It was not, however, until the electrical illumination of rarefied gases came to be studied with detailed attention that the full effect of the visual identity of the two kinds of phenomenon became sensible. The analogy was defined and completed by some experiments made by De la Rive in 1853. They showed that a luminous discharge in an exhausted vessel, when influenced by a powerful electro-magnet, condenses into a ring of light encircling its pole, endowed, moreover, with a rotatory movement such as has frequently been observed to affect a system of auroral streamers. Here, for the first time, their true part in such displays was assigned to the forces emanating from the earth's magnetic poles. It is a directive, not a formative one. The structure, not the occurrence, of auroræ is conditioned by them.

A marked change in scientific opinion resulted, accordingly, from these investigations. The "magnetic effluvium" theory of the aurora borealis finally disappeared, and what we may call the "illuminated vacuum" theory took its place. The change was accompanied by a shifting of the ground of inquiry. What was urgently needed in order to render intelligible the mode of action producing the gorgeous flame-vesture of northern skies, was perceived to be, not so much improved knowledge (however desirable) of the laws of terrestrial magnetism, as a sound doctrine of atmospheric electricity. Here De la Rive broke down. His hypothesis of a polar accumulation, through the agency of the winds, of the positive charge of the air, was obviously untenable.

Nothing better was, however, proposed until 1878, when Prof. Edlund, of Stockholm, applied the principle of "unipolar induction," discovered by Weber in 1841, to explain the phenomena of atmospheric electricity (*Phil. Mag.*, vol. vi. p. 360). The effects thus designated are really derived, as a particular case (in M. Edlund's probable view), from the well-established laws of magnetic action upon electric currents.

Each element of the system of currents formed by the electrified particles of the rotating terrestrial crust and atmosphere is thus urged, by the powerful magnet which the earth may legitimately be regarded as inclosing within it, along a path at right angles to the line drawn from each of its poles to the current-element. The direction and relative strength of the impelling forces are indicated in the accompanying figure, copied from the work before us (p. 166), where the particle *m′* is solicited towards × by the south pole (pointing north) of the magnet *Sn*, and towards *g* by its south pole. The combined result is to drive the particle upward and poleward along a line everywhere perpendicular to the swing of the dipping-needle. The vertical component, accordingly (represented by the arrows standing erect on the circle $m' \; m'' \; m'''$), attains a maximum at the magnetic equator, where the dip vanishes; the tangential component is there = 0, and attains its highest value in middle latitudes.



Several remarkable effects ensue: first, that atmospheric electricity gains potential with elevation—an observed fact; next, that it is constantly travelling away from the equator towards either pole. The circulatory process, however, thus set on foot, must be carried further; and in its continuance and completion M. Edlund finds the key to the auroral mystery.

At and near the equator, recomposition of the positive electricity of the air with the negative electricity of the earth is opposed by the whole strength of magnetic inductive repulsion, there acting vertically. When effected at all, it can only then be by sudden, violent, disruptive discharges, apparent to our senses as lightning. But the increasing inclination of the magnetic needle in higher latitudes renders the line of no resistance marked by it continually more practicable as an avenue of descent for the accumulating positive fluid. Hence, when it has attained a certain potential, gradual discharges take place over two polar zones, *along the line of the dipping-*

needle. These constitute what we are accustomed in the northern hemisphere to call the aurora borealis.

Auroræ are, in this view, the polar equivalents of lightning. The same office of relieving the electrical tension of the air is fulfilled by them with innocuous tranquillity. Not indeed in absolute silence, though the "eerie din" of their rustling streamers has been caught by very few ears. Major Dawson, however, was fortunate enough to hear once, and once only, during his sojourn at Fort Rae, 1882-83, a sound "like the swishing of a whip, or the noise produced by a sharp squall of wind in the upper rigging of a ship," which accompanied, with its *crescendo* and *diminuendo*, the brightening and fading of an aurora visible at the time. This was the first official confirmation of innumerable less authentic reports to the same effect.

The mutual relations of auroræ and thunderstorms are full of significant interest. In point of geographical distribution, they may be termed complementary. The one kind of phenomenon is not more characteristically of polar than the other is of tropical origin. We take from M. Lemström's pages the following concise table, strongly corroborative of Edlund's theory, showing the dependence upon latitude of storm-frequency:—

Latitude		Mean annual number of storms
Between 0° and 30°	...	52
„ 30 „ 50	...	20
„ 50 „ 60	...	15
„ 60 „ 70	...	10
About 70	...	0

Yet the two kinds of atmospheric luminosity are separated by profound distinctions. Thunderstorms give no sign of systematic magnetic associations. Sometimes, it is true, the needle may be seen to quiver at the instant of a lightning-flash, but by what seems a casual disturbance, quite different from the tumultuous agitation which accompanies or even betrays the darting of northern lights.

Storms are, moreover (so far as is known), completely exempt from the complicated periodicity by which auroral appearances are regulated. Now this, as M. Tromholt discovered in 1882, is exactly inverted in the far north. His discussion of M. Kleinsmidt's observations (1864-80) at Godthaab in North Greenland made it apparent that, on the polar side of the great auroral zone, a sunspot maximum brings with it an auroral minimum, and *vice versâ*; that the two equinoctial peaks of the auroral curve in middle latitudes there coalesce into a single elevation at the winter solstice; and that the evening maximum noted further south is there shifted to the morning. Nor are these curious inversions peculiar to Godthaab.

Their immediate cause is easily understood. The auroral zone swings to and fro in several superposed periods, over the surface of the earth. As the sun's activity augments, it travels slowly towards the equator, and retreats towards the pole as it diminishes, diversifying its progress with minor oscillations, daily, bi-annual, and (perhaps) monthly. The analogy of the closing-in of the solar spot-zones with approach to maximum is striking, but unexplained. Auroral periodicity is thus seen to depend, not upon cessation, but upon removal, and the observed reciprocal relation between auroral frequency in middle and very high latitudes is completely accounted for.

We can even go a step further. By Edlund's theory an increase of atmospheric electricity must be attended by a lowering of the latitude in which recomposition takes place. That is to say, the observed shifting in space of the auroral zone implies, and is explained by, a rise and fall of potential in the upper conducting strata of the air, synchronising with the rise and fall of solar disturbance. This is probably in part an indirect effect of the fluctuations in the sun's activity.

Electricity, in M. Edlund's view, is simply the ether of space, a certain share of which belongs naturally to every ponderable substance. When this normal store is by any means augmented, the body on which the accumulation takes place is positively electrified; when it is diminished, negative electrification ensues. Hence, the expulsion of this so-called "fluid" from the earth by magnetic inductive action leaves it, *ipso facto*, negatively charged, and produces a positive charge in the air.

All this M. Lemström, in the work before us, readily admits; but he supplements the magnetic forces at work in disturbing our planet's electrical equilibrium with evaporation, of which the enormous capabilities for producing high potentials have been indicated by Prof. Tait (NATURE, vol. xxix. p. 517). But evaporation doubtless proceeds most vigorously when the sun's radiative energy is strongest—that is (presumably), at epochs of spot-maximum, so that an obvious link is thus supplied between the solar and auroral periods. The sequence of cause and effect is as follows: the sun's increased power quickens the development of aqueous vapour; this, in its turn, gives rise to a more copious supply of atmospheric electricity; added tension insures more speedy neutralisation; the zone of gradual recomposition descends towards the equator, and auroræ are more frequently visible in middle latitudes.

Yet this is perhaps not the whole truth. Many circumstances speak in favour of a direct electrical inductive action of the sun upon the earth. M. Quet has lately shown (*Comptes rendus*, t. xcviii. p. 1038) that the existence of a magnetic fluctuation corresponding in period with the sun's rotation on its axis is otherwise inexplicable; and the instantaneous response of the terrestrial magnetic system to the solar outburst of September 1, 1859, almost compels the same inference, which is strengthened by the undoubted growth of magnetic intensity with solar activity. Hence, as sunspots become numerous, the circulatory process described by M. Edlund must be quickened and strengthened; atmospheric electrical tension will be heightened; and although the repellent magnetic power is proportionately reinforced, this is more than counterbalanced by the added mutual attraction between the opposite electricities of earth and air. Through this cause also, then, the auroral zone widens its distance from the pole once in eleven years.

The view that auroræ are due to currents of positive electricity illuminating the air on their passage to the earth, has been solidly established by M. Lemström's results at Sodankylä. His "discharging apparatus" served the precise purpose of Franklin's kite. The one experiment was not more decisive than the other. Not only did luminous appearances accompany the setting-in of a current towards the earth from the network of insulated wires spread over the summit of Mount Oratunturi, but the light evoked was distinctively *auroral.* Examined with the spectroscope, it yielded the still enigmatical "citron-line" discovered by Ångström in 1867. This is the invariable and chief constituent of auroral radiations. Besides one fitfully present, detected by Zöllner in the red, it is the only vivid line its spectrum includes. Ten others, more or less dubiously enumerated, are faint, hazy, indeterminate. M. Lemström holds that there is a fair agreement between some of them and lines in the laboratory-spectrum of rarefied air. But this is perhaps a too sanguine opinion. These seeming coincidences are very loose, and have not been drawn closer by careful inquiry. Vogel's conclusion that the spectrum of the aurora is modified from that of atmospheric air is indeed highly probable, but its probability is derived far more from external than from internal evidence.

A. M. CLERKE

THE BUTTERFLIES OF INDIA

The Butterflies of India, Burmah, and Ceylon. A Descriptive Hand-book of all the Known Species of Rhopalocerous Lepidoptera inhabiting that Region, with Notices of Allied Species occurring in the Neighbouring Countries along the Border. With Numerous Illustrations. By Lionel de Nicéville, F.E.S. Vol. II. Royal 8vo. (Calcutta. London: Bernard Quaritch, 1886.)

MORE than four years have elapsed since the first part of this book was published, and one of the authors has been obliged to resign his share in the work. The second volume, which has been written by Mr. de Nicéville alone, is in no way inferior to the first. When we remember that in the trying climate of Calcutta, and only in the leisure hours which can be spared from official work, Mr. de Nicéville has with but very trifling assistance from the Government of India completed a volume of nearly 300 pages, containing over 300 species of butterflies, we must allow that he deserves great praise; and though a volume produced under such difficulties must of necessity contain faults, yet it is in every respect very superior to Mr. Moore's work on the Lepidoptera of Ceylon, which was largely subsidised by Government. There is no doubt that the impetus given to the study of the butterflies of India by the publication of this work will have the best results, and we have every reason to hope and believe that it may be completed in three or four years more at latest. The present volume is devoted almost entirely to the family of Nymphalinæ, and brings up the number of Indian butterflies already described to over 600, all of which are treated in a thoroughly scientific, careful, and painstaking manner.

Though the author has gathered to his assistance a growing band of field workers in various parts of India, among whom Messrs. Möller, Knyvett, Graham-Young, Colonel Swinhoe, and others are conspicuous, and is rapidly accumulating a large quantity of specimens from all parts of the country, he still labours under the difficulty of being unable to see the types of many of the so-called species described by Messrs. Butler and Moore in Europe. Evidence is constantly being brought forward to confirm the opinion of most entomologists, that a large proportion of the names given by these authors represent no fixed or constant varieties, and that the characters described by them cannot be recognised in the insects themselves; but it is impossible to ignore them until this can be proved by comparison of these types with large series of specimens. Under these circumstances, Mr. de Nicéville has acted wisely in printing the descriptions of all these doubtful species, so that the attention of collectors may be called to them, and their existence proved or disproved. His remarks on them have the advantage of being intelligible, which is not always the case with the original descriptions of the authors in question, who have had for some years almost a monopoly in the description of Indian butterflies.

The kind of difficulty which occurs in many instances may be illustrated by the author's final remarks on the numerous varieties of the genus Abisara, described as species by Mr. Moore.

"A *prunosa* is typically the darkest coloured, and in the male most brilliantly purple-shot, of this group of the genus, specimens from Travancore being particularly large and dark. Even among Ceylon specimens, however, I find considerable variation; in some males the inner discal band on the fore-wing is evenly convex, and in others distinctly angled in the middle, and the purple suffusion is also variable; the size and number of the black spots on both sides of the hind-wing is extremely inconstant. In one very abnormal specimen there are two sub-apical spots, only the anal ones being entirely wanting. From an island one would expect to find some distinguishing characters in a species supposed to be peculiar to it, but I have quite failed to discover any. I can only repeat that, in my opinion, the name *echerius* should apply to all the species of this group of the genus Abisara, except perhaps to the Andaman local race, which has been named *bifasciata;* that as, in this case, the geographical range of numerous slight local races is not segregated, and each local race must interbreed with the next on the boundary-line which is supposed to separate them, it can serve no good scientific purpose to pick out a few apparently different specimens from each local race and to describe them, at the same time ignoring the intergrade specimens which exist."

If this opinion had been more generally held, the study of the butterflies of India would have been much simplified, and it is to be hoped that a new edition of "The Butterflies of India," which will certainly be called for almost before the first is complete, will show a large reduction in the number of names. A fixed nomenclature is the first desideratum in this as in other branches of science, and tends more than anything to attract good workers, who are often disgusted by a long list of synonyms and by changes in well-known old names.

The keys to the genera and species have been worked out very carefully, and will be useful to beginners. The literature, geographical distribution, and variation of each species are also well and carefully done. The volume will be indispensable to lepidopterists generally, and ought to interest many in India, who have hitherto looked on the collection of butterflies as rather a pastime than a science.

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